

ORDINANCE 122738

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AN ORDINANCE relating to environmentally critical areas, amending Sections 22.802.020, 23.47A.012, 23.47A.013, 23.54.020, 25.09.015, 25.09.020, 25.09.030, 25.09.055, and 25.09.520, and adding a new Section 25.09.110 of the Seattle Municipal Code to designate and regulate Peat Settlement-prone Geologic Hazard Areas.

WHEREAS, peat-rich soils are prone to settlement, and therefore, development in areas underlain by, or in the vicinity of peat-rich soils may impact nearby parcels, and

WHEREAS, the Department of Planning and Development (DPD) has followed the Guidelines adopted by the Washington State Department of Community Trade and Economic Development, and in consideration of the Growth Management Act, as set out in the Best Available Science Report for Peat Settlement-prone Areas, attached as Exhibit B; and

WHEREAS, DPD has prepared regulations for development in areas with peat-rich soils in consideration of the public interest, and has met with affected communities in and around mapped peat deposits. NOW, THEREFORE,

BE IT ORDAINED BY THE CITY OF SEATTLE AS FOLLOWS:

Section 1. Subsection A of Section 22.802.020 of the Seattle Municipal Code, which Section was last amended by Ordinance 119965, is amended as follows:

22.802.020 Drainage control review and application requirements.

A. Thresholds for Drainage Control Review. Drainage control review and approval shall be required for any of the following:

1. Standard drainage control review and approval shall be required for the following:
 - a. Any land disturbing activity encompassing an area of seven hundred fifty (750) square feet or more;
 - b. Applications for either a master use permit or building permit that includes the cumulative addition of seven hundred fifty (750) square feet or more of land disturbing activity and new and replaced impervious surface;
 - c. Applications for which a grading permit or approval is required;



1 d. Applications for street use permits for the cumulative addition of seven
2 hundred fifty (750) square feet or more of new and replaced impervious surface and land
3 disturbing activity after the effective date of the ordinance codified in this subtitle;

4 e. City public works project or construction contracts, including contracts
5 for day labor and other public works purchasing agreements, for the cumulative addition of seven
6 hundred fifty (750) square feet or more of new and replaced impervious surface and land
7 disturbing activity to the site after the effective date of the ordinance codified in this subtitle,
8 except for projects in a City-owned right-of-way and except for work performed for the operation
9 and maintenance of park lands under the control or jurisdiction of the Department of Parks and
10 Recreation;

11 f. Permit approvals and contracts that include any new or replaced
12 impervious surface on a site deemed a potentially hazardous location, as specified in Section
13 22.800.050; (~~or~~)

14 g. Permit approvals that include any new impervious surface in a Category
15 I peat settlement-prone area delineated pursuant to Section 25.09.020; or

16 ~~(g)~~h. Whenever an exception to a requirement set forth in this subtitle or
17 in a rule promulgated under this subtitle is desired, whether or not review and approval would
18 otherwise be required, including but not limited to, alteration of natural drainage patterns or the
19 obstruction of watercourses.

20 2. Large project drainage control review and approval shall be required for
21 projects that include:

22 a. Five thousand (5,000) square feet or more of new or replaced
23 impervious surface; or

24 b. One (1) acre or more of land disturbing activity.



1 (b) A residential use is located on a street-level, street
2 facing facade, and the first floor of the structure at or above grade is at least four (4) feet above
3 sidewalk grade; and

4 (2) The additional height allowed for the structure will not allow an
5 additional story beyond the number that could be built under the otherwise applicable height
6 limit.

7 b. The height of a structure may exceed the otherwise applicable limit by
8 up to seven (7) feet, subject to subsection A1c of this section, provided all of the following
9 conditions are met:

10 (1) Residential and multipurpose retail sales uses are located in the
11 same structure;

12 (2) The total gross floor area of at least one (1) multi-purpose retail
13 sales use exceeds twelve thousand (12,000) square feet;

14 (3) A floor-to-floor height of sixteen (16) feet or more is provided
15 for the multi-purpose retail sales use at street level;

16 (4) The additional height allowed for the structure will not allow an
17 additional story beyond the number that could be built under the otherwise applicable height
18 limit if a sixteen (16) foot floor-to-floor height were not provided at street level; and

19 (5) The structure is not allowed additional height under subsection
20 A1a of this section.

21 c. The Director shall reduce or deny the additional structure height
22 permitted by this subsection A1 if the additional height otherwise would significantly block
23 views from neighboring residential structures of any of the following: Mount Rainier, the
24 Olympic and Cascade Mountains, the downtown skyline, Green Lake, Puget Sound, Lake
25 Washington, Lake Union and the Ship Canal.

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1 2. For any lot within the designated areas shown on Map 23.47A.012 A, the
2 maximum structure height in NC zones or C zones with a forty (40) foot height limit may be
3 increased to sixty-five (65) feet, provided that all portions of the structure above forty (40) feet
4 contain only residential uses, and provided that no additional height is allowed under subsection
5 A1 of this section.

6 3. Monorail transit facilities may exceed the height limit of the zone according to
7 the provisions of Section 23.80.004 or Section 15.54.020.

8 4. Within the South Lake Union Urban Center, maximum structure height shall be
9 determined according to the provisions of the Seattle Mixed Zone, Section 23.48.010.

10 5. Within the Station Area Overlay District within the University District
11 Northwest Urban Center Village, maximum structure height may be increased to one hundred
12 twenty-five (125) feet when all of the following are met:

13 a. The lot is within two (2) blocks of a planned or existing light rail
14 station;

15 b. The proposed use of the lot is functionally related to other office
16 development, permitted prior to 1971, to have over five hundred thousand (500,000) square feet
17 of gross floor area to be occupied by a single entity;

18 c. A transportation management plan for the life of the use includes
19 incentives for light rail and other transit use by the employees of the office use;

20 d. The development shall provide street level amenities for pedestrians and
21 shall be designed to promote pedestrian interest, safety, and comfort through features such as
22 landscaping, lighting and transparent facades, as determined by the Director; and

23 e. This subsection can be used only once per functionally related
24 development.

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1 6. On a lot containing a peat settlement-prone environmentally critical area, the height of
2 a structure may exceed the otherwise applicable height limit and the other height allowances
3 provided by this section by up to three (3) feet. In addition, three (3) more feet of height may be
4 allowed for any wall of a structure on a sloped lot, provided that on the uphill side(s) of the
5 structure, the maximum elevation of the structure height shall be no greater than the height
6 allowed by the first sentence of this subsection A6 (Exhibit 23.47A.012 A). The Director may
7 apply the allowances in this subsection A6 only if the following conditions are met:

8 a. The Director finds that locating a story of parking underground is infeasible due
9 to physical site conditions such as a high water table;

10 b. The Director finds that the additional height allowed for the structure is
11 necessary to accommodate parking located partially below grade that extends no more than six (6)
12 feet above existing or finished grade and no more than three (3) feet above the highest existing or
13 finished grade along the structure footprint, whichever is lower, as measured to the finished floor
14 level above; and

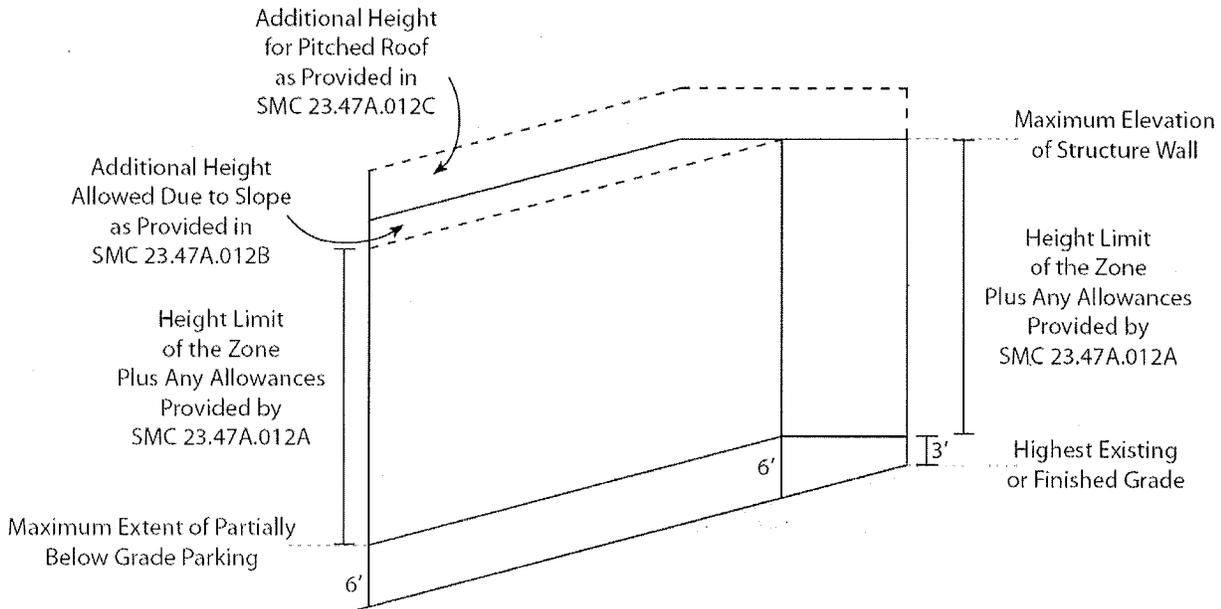
15 c. Other than the additional story of parking allowed pursuant to this subsection
16 A6, the additional height allowed for the structure by this subsection A6 will not allow an
17 additional story beyond the number of stories that could be built under the otherwise applicable
18 height limit.



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Exhibit 23.47A.012A

Height Allowance on Lots Containing Peat Settlement-Prone Areas



Section 3. Subsections A and D of section 23.47A.013 of the Seattle Municipal Code, which Section was last amended by Ordinance 122311, is amended as follows:

23.47A.013 Floor area ratio.

A. Floor area ratio (FAR) limits apply to all structures and lots in all NC zones and C zones.

1. All gross floor area not exempt under subsection D of this Section is counted against the maximum gross floor area allowed by the permitted FAR.



1 finds that locating a story of parking below grade is infeasible due to physical site conditions
2 such as a high water table, if either:

3 a. the above-grade parking extends no more than six (6) feet above existing
4 or finished grade and no more than three (3) feet above the highest existing or finished grade
5 along the structure footprint, whichever is lower, as measured to the finished floor level or roof
6 above, as depicted in Exhibit 23.47A.012A; or

7 b. all of the following conditions are met:

8 (1) no above-grade parking is exempted by subsection D6a

9 (2) the parking is accessory to a residential use on the lot;

10 (3) total parking on the lot does not exceed 1 space for each
11 residential dwelling unit plus the number of spaces required by this Code for non-residential
12 uses; and

13 (4) the amount of gross floor area exempted by this subsection D6b
14 does not exceed twenty-five (25) percent of the area of the lot in zones with a height limit less
15 than sixty-five (65) feet, or fifty (50) percent of the area of the lot in zones with a height limit
16 sixty-five (65) feet or greater.

17 ***

18 Section 4. Section 23.54.020 of the Seattle Municipal Code, which section was last
19 amended by Ordinance 122311, is amended to add a new subsection K as follows:

20 **23.54.020 Parking quantity exceptions.**

21 The parking quantity exceptions set forth in this section apply in all zones except
22 downtown zones, which are regulated by Section 23.49.019, and Major Institution zones, which
23 are regulated by Section 23.54.016.

24 * * *



1 K. Peat Settlement-prone Environmentally Critical Areas. Except in Single-family,
2 Residential Small Lot, and Lowrise zones, the Director may reduce or waive the minimum
3 accessory off-street parking requirements to the minimum extent necessary to offset underground
4 parking potential lost to limitations set forth in Section 25.09.110 on development below the
5 annual high static groundwater level in peat settlement-prone areas. In making any such
6 reduction or waiver, the Director will assess area parking needs. The Director may require a
7 survey of on- and off-street parking availability. The Director may take into account the level of
8 transit service in the immediate area; the probable relative importance of walk-in traffic;
9 proposals by the applicant to encourage carpooling or transit use by employees; hours of
10 operation; and any other factor or factors considered relevant in determining parking impact.

11 Section 5. Subsection A of Section 25.09.015 of the Seattle Municipal Code, which
12 Section was last amended by Ordinance 122370, is amended as follows:

13 **25.09.015 Application of chapter**

14 A. This chapter applies to any development, as defined in Section 25.09.520, or platting
15 carried out by any person on publicly or privately owned parcels containing an environmentally
16 critical area or buffer, except that parcels that are solely within seismic or volcanic hazards areas,
17 as defined in Sections 25.09.020.A.~~((5))~~6 and 25.09.020.A.~~((6))~~7, and that are not liquefaction-
18 prone areas are subject only to Sections 25.09.010, 25.09.017.A, B, C and F, 25.09.020, and
19 25.09.030.

20 Section 6. Section 25.09.020 of the Seattle Municipal Code, which Section was last
21 amended by Ordinance 122370, is amended as follows:

22 **25.09.020 Environmentally critical areas definitions.**

23 The following are environmentally critical areas designated by this chapter: geologic
24 hazard areas, steep slope areas, flood-prone areas, wetlands, fish and wildlife habitat
25 conservation areas, and abandoned landfills.



1 For the purpose of this definition, a slope is measured by establishing its toe and top and
2 averaging the inclination over at least ten feet (10') of elevation difference.

3 Also for the purpose of this definition:

4 (a) The "toe" of a slope means a distinct topographic break
5 in slope that separates slopes inclined at less than forty percent (40%) from slopes inclined at
6 forty percent (40%) or more. Where no distinct break exists, the "toe" of a slope is the lower-
7 most limit of the area where the ground surface drops ten feet (10') or more vertically within a
8 horizontal distance of twenty-five feet (25'); and

9 (b) The "top" of a slope is a distinct topographic break in
10 slope that separates slopes inclined at less than forty percent (40%) from slopes inclined at forty
11 percent (40%) or more. Where no distinct break exists, the "top" of a slope is the upper-most
12 limit of the area where the ground surface drops ten feet (10') or more vertically within a
13 horizontal distance of twenty-five feet (25').

14 (6) Areas that would be covered under one of subsections (2) to
15 (5), but where the topography has been previously modified through the provision of retaining
16 walls or non-engineered cut and fill operations;

17 (7) Any slope area potentially unstable as a result of rapid stream
18 incision or stream bank erosion.

19 4. Steep Slope Areas. Steep slope areas are areas with a slope described in
20 subsection A3b(5) above; provided that when such a slope is on a parcel in a Downtown zone or
21 highrise zone, the area is designated only as a landslide prone area.

22 5. Peat Settlement-prone Areas.

23 a. Peat settlement-prone areas, which consist of Category I and Category II
24 peat settlement-prone areas, are delineated on Maps A1 through A26, Peat Settlement-prone
25 Area Boundaries Maps, codified at the end of this chapter.



1 b. The Director may, at the request of the owner of a parcel larger than
2 50,000 square feet, provide a parcel-specific delineation of the peat settlement-prone area
3 boundary on that parcel. Where a parcel-specific delineation conflicts with the Peat Settlement-
4 prone Area Boundaries Maps, the parcel-specific delineation shall apply. The parcel-specific
5 delineation is based on the location of the relevant bog or bogs identified in *City of Seattle*
6 *Identified Bogs* (Troost 2007) plus a buffer of 50 feet for Category I peat settlement-prone areas
7 or a buffer of 25 feet for Category II peat settlement-prone areas.

8 ((5))6. Seismic Hazard Areas. In addition to liquefaction-prone areas described
9 in subsection 2 above, seismic hazard areas are the following:

10 a. Areas of the City subject to ground shaking from seismic hazards that
11 are addressed by the Building Code (SMC Title 22).

12 b. The Seattle Fault zone as delineated in Troost et al., 2005, *The geologic*
13 *map of Seattle, a progress report, U.S. Geological Survey, Open-file report 2005-1252* or as the
14 Director determines is more accurately mapped by the U.S. Geological Survey, as set out in a
15 Director's Rule.

16 c. For tsunamis the waterbody of Lake Washington and for tsunamis and
17 tsunami inundation, the water body and land area as shown in Walsh, et al., 2003, *Tsunami*
18 *hazard map of the Elliott Bay area, Seattle, Washington: Modeled tsunami inundation from a*
19 *Seattle Fault earthquake, Washington State Department of Natural Resources and National*
20 *Oceanic and Atmospheric Administration. Washington Division of Geology and Earth Resources*
21 *Open File Report 2003-14*, or as the Director determines are more accurately mapped by the
22 National Oceanic and Atmospheric Administration, the U.S. Geological Survey or the
23 Washington State Department of Natural Resources, as set out in a Director's Rule.

24 d. The shoreline and upland areas surrounding Lake Washington are
25 classified as an unknown risk from tsunamis under WAC 365-190-080 (4)(b)(iii).



1 e. For seiches, the waterbodies of Elliot Bay, Lake Union and Lake
2 Washington.

3 f. The shoreline and upland areas surrounding the waterbodies in
4 subsection (e) are classified as an unknown risk from seiches under WAC 365-190-080 (4)(b)(iii)

5 ~~((6))~~7. Volcanic Hazard Areas. Volcanic hazard areas are areas subject to
6 inundation by lahars or related flooding resulting from volcanic activity on Mount Rainier, as
7 delineated by the U.S. Geological Survey in Hoblitt, et.al, 1998, *Volcano Hazards from Mount*
8 *Rainier, Washington, Revised 1998: U.S. Geological Survey Open-File Report 98-428*, or as the
9 Director determines are more accurately mapped by the U.S. Geological Survey, as set out in a
10 Director's Rule.

11 ***

12 Section 7. Section 25.09.030 of the Seattle Municipal Code, which Section was last
13 amended by Ordinance 122370, is amended as follows:

14 **25.09.030 Location of environmentally critical areas and buffers.**

15 A. Environmentally critical areas are defined in Section 25.09.020, and buffers are
16 described in Sections 25.09.160, 25.09.180, and 25.09.200B. Environmentally critical areas are
17 mapped whenever possible. Except for the maps adopted as designations for geologically
18 hazardous areas in subsections 25.09.020.A.5 ~~((and))~~, 6, and 7, these maps are advisory. The
19 Director may update or amend the maps by Director's Rule.

20 B. The Director shall determine whether a parcel contains an environmentally critical
21 area or buffer before other provisions of this chapter are applied. In determining whether a parcel
22 contains an environmentally critical area or buffer, the Director may consider the
23 environmentally critical areas maps, site surveys, topographic maps, technical environmental
24 analysis, and any other information the Director determines necessary. In determining whether
25 development is subject to regulation under Section 25.09.110, the Director may consider only



1 whether the development will occur within an area delineated pursuant to subsection 25.09.020

2 A5.

3 Section 8. Subsection A of Section 25.09.055 of the Seattle Municipal Code, which
4 Section was last amended by Ordinance 122050, is amended as follows:

5 **25.09.055 Small project waiver.**

6 A. The Director may approve new accessory structures or additions to existing structures
7 in the environmentally critical areas and buffers listed in subsection A2, provided that no
8 construction occurs over or in a water course, water body, or wetland, when the applicant
9 demonstrates the proposal meets the following criteria:

10 1. The new accessory structure or addition to an existing structure is on a lot that
11 has been in existence as a legal building site prior to October 31, 1992.

12 2. The development does not exceed one hundred and fifty (150) square feet in
13 riparian management areas or in wetland buffers, three hundred (300) square feet in steep slope
14 areas or buffers, or seven hundred fifty (750) square feet in landslide-prone (except steep slope),
15 liquefaction-prone, flood-prone, and abandoned land fill areas, all calculated cumulatively from
16 October 31, 1992. When the new accessory structure or addition to an existing structure is on a
17 lot that is or has been held in common ownership with a contiguous lot and the lots are or have
18 been used for a single principal use or for a principal use and accessory use, the limitation applies
19 to the entire site.

20 3. It is not possible to build the accessory structure or addition to an existing
21 structure for the intended purpose out of the environmentally critical area or buffer.

22 4. The location of the accessory structure or addition to an existing structure keeps
23 impact on the environmentally critical area and buffer to a minimum.



1 H. In addition to requiring the information provided pursuant to Section 25.09.330 and to
2 Director's Rules, the Director may require third-party review when the professional opinions of
3 the applicant's representative and the Department's reviewers cannot be reconciled. Third-party
4 review requires the applicant's geotechnical and/or additional technical studies to be reviewed by
5 an independent third party, paid for by the applicant but hired by the Director. Third-party review
6 shall be conducted by a qualified engineering consultant.

7 I. The Director may waive compliance with some or all of the requirements of
8 subsections B - G for a project in a Category II peat settlement-prone area to the extent the
9 applicant demonstrates to the satisfaction of the Director that the project has been designed to
10 avoid adverse impacts to off-site parcels from peat settlement. Such impacts include but are not
11 limited to any adverse, off-site effect resulting from temporary dewatering during construction,
12 groundwater inflow due to normal operation and maintenance of underground structures,
13 groundwater inflow due to potential future leaks that could occur in underground structures, and
14 reduced impervious surface. Projects qualifying for a waiver under this subsection may include
15 but are not limited to the following:

- 16 1. Projects involving concurrent removal of all peat contained in an entire peat
17 settlement-prone area;
- 18 2. Concurrent development or redevelopment of the entire peat settlement-prone
19 area that is designed to minimize modification of the groundwater table and avoid impacts of
20 future settlement through design of new structures; or
- 21 3. Projects that are designed to minimize modification of the groundwater regime
22 and that avoid potential adverse, off-site settlement impacts by retrofitting existing structures on
23 off-site parcels within the entire peat settlement-prone area.

24 J. Standards for height and floor area ratio may be modified on lots containing a peat
25 settlement-prone environmentally critical area as provided in 23.47A.012 and 23.47A.013.



1 K. Nothing in this section (including but not limited to subsection I) limits the authority
2 of the Director pursuant to other applicable codes or regulations (including but not limited to
3 Title 22, Subtitles I and IA, the Building Code and Residential Code) to require additional
4 studies or impose additional conditions to address project-related risks arising in peat settlement-
5 prone areas.

6 Section 10. Section 25.09.520 of the Seattle Municipal Code, which Section was last
7 amended by Ordinance 122050, is amended as follows:

8 **25.09.520 Definitions.**

9 ***
10 “Annual high static groundwater level” means the highest elevation where the soil is saturated
11 with the main body of groundwater during any part of the year.

12 ***
13 “Contaminated soils” is defined in Section 21.36.012, Solid Waste Code.

14 ***
15 “Groundwater regime” means the amount, distribution, and seasonal variation of water below the
16 surface of the land.

17 ***
18 “Infiltration facility” is defined in Section 22.801.100, Stormwater, Grading and Drainage
19 Control Code.

20 ***
21 “Utility lines” means pipes, cables or other linear conveyance systems used to transport power,

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1 water, gas, oil, wastewater or similar items.

2 ***

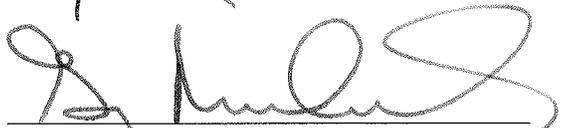
3 Section 11. The provisions of this ordinance are declared to be separate and severable.
4 The invalidity of any particular provision shall not affect the validity of any other provision.

5 Section 12. This ordinance shall take effect and be in force thirty (30) days from and
6 after its approval by the Mayor, but if not approved and returned by the Mayor within ten (10)
7 days after presentation, it shall take effect as provided by Municipal Code Section 1.04.020.

8
9 Passed by the City Council the 14th day of July, 2008, and signed by me in open
10 session in authentication of its passage this 14th day of July, 2008.

11
12 
13 President _____ of the City Council

14 Approved by me this 23rd day of July, 2008.

15
16 
17 Gregory J. Nickels, Mayor

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19 Filed by me this 23 day of July, 2008.

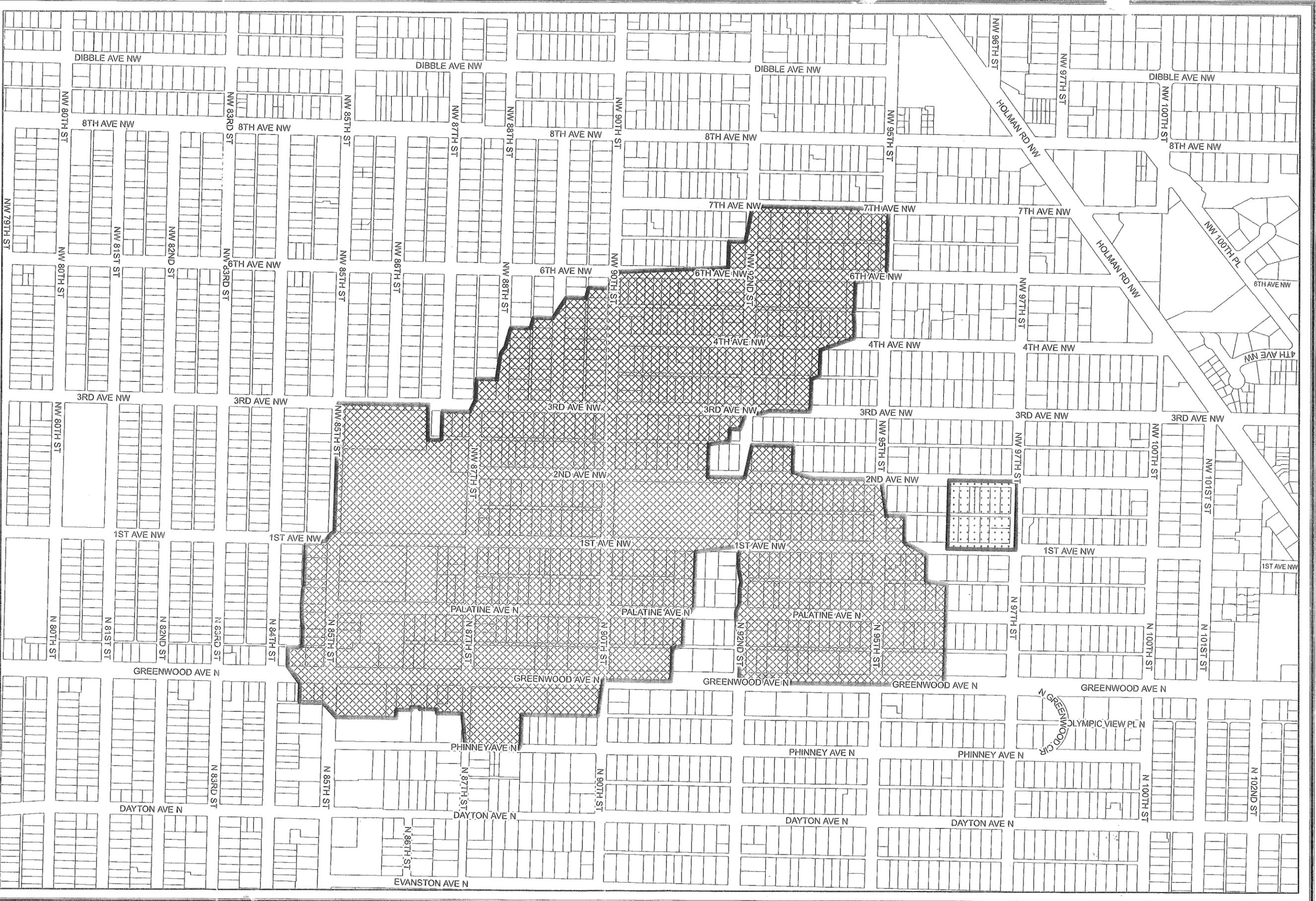
20
21 
22 City Clerk

23 (Seal)

24 Exhibit A: Peat Settlement-prone Areas Boundaries Maps A1 – A26

25 Exhibit B: Best Available Science Report for Peat Settlement-prone Areas





Peat Settlement-prone Area Boundaries Maps

Map A 1

Legend

Peat Settlement-Prone Area

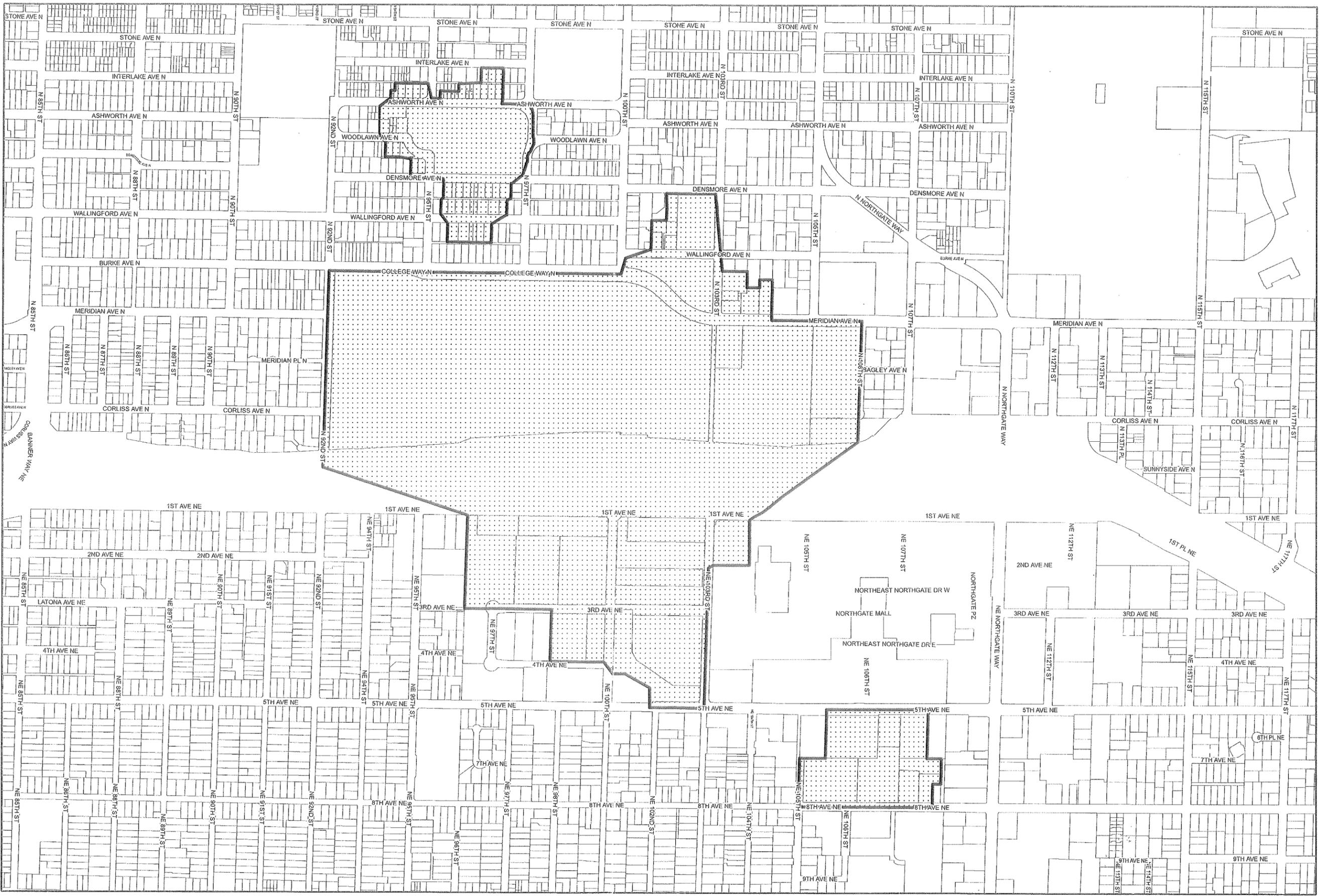
- Category I
- Category II

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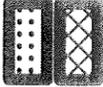


Peat Settlement-prone Area Boundaries Maps

Map A 2

Legend

Peat Settlement-Prone Area

-  Category I
-  Category II

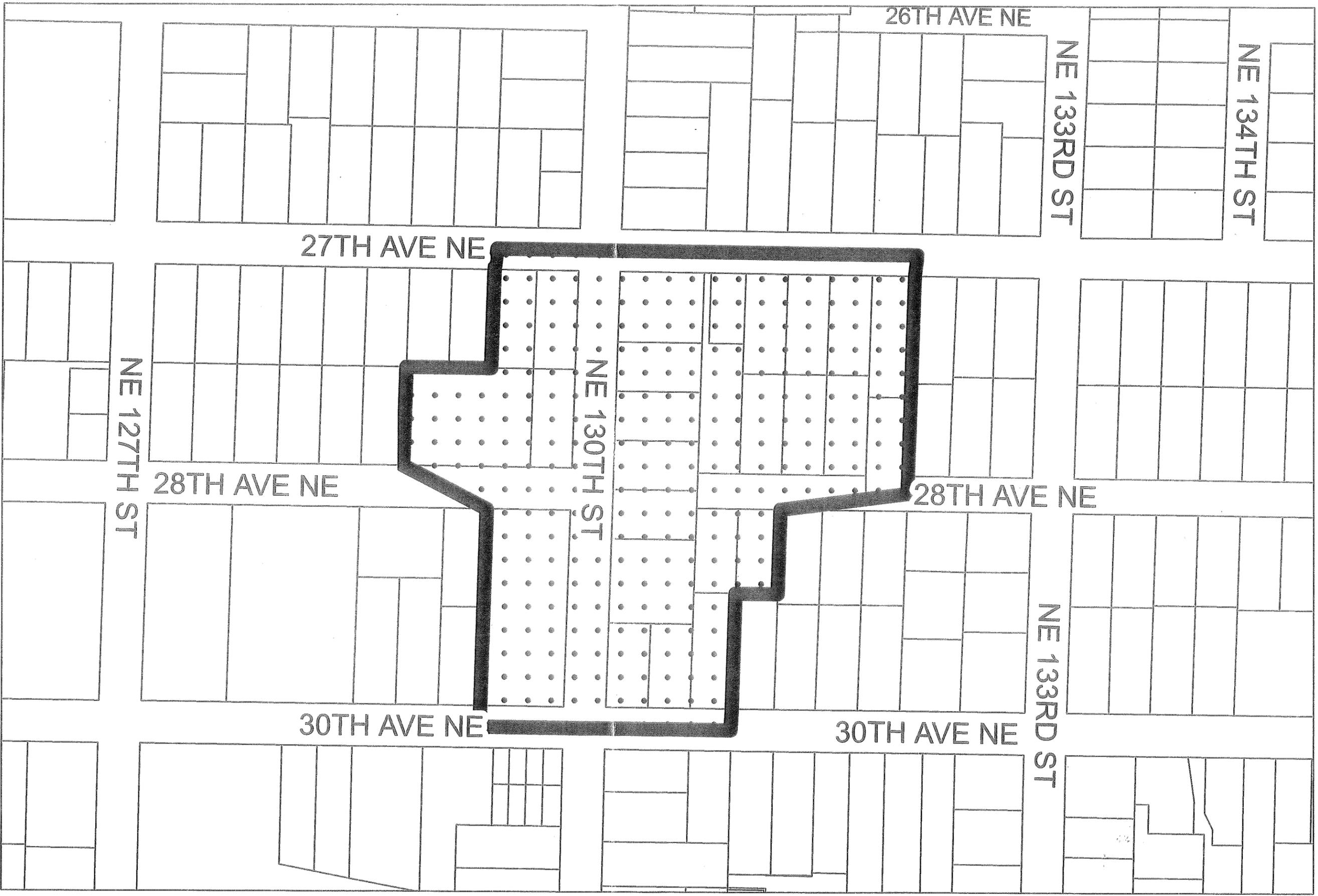
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**Peat Settlement-prone
Area Boundaries Maps**

Map A 3

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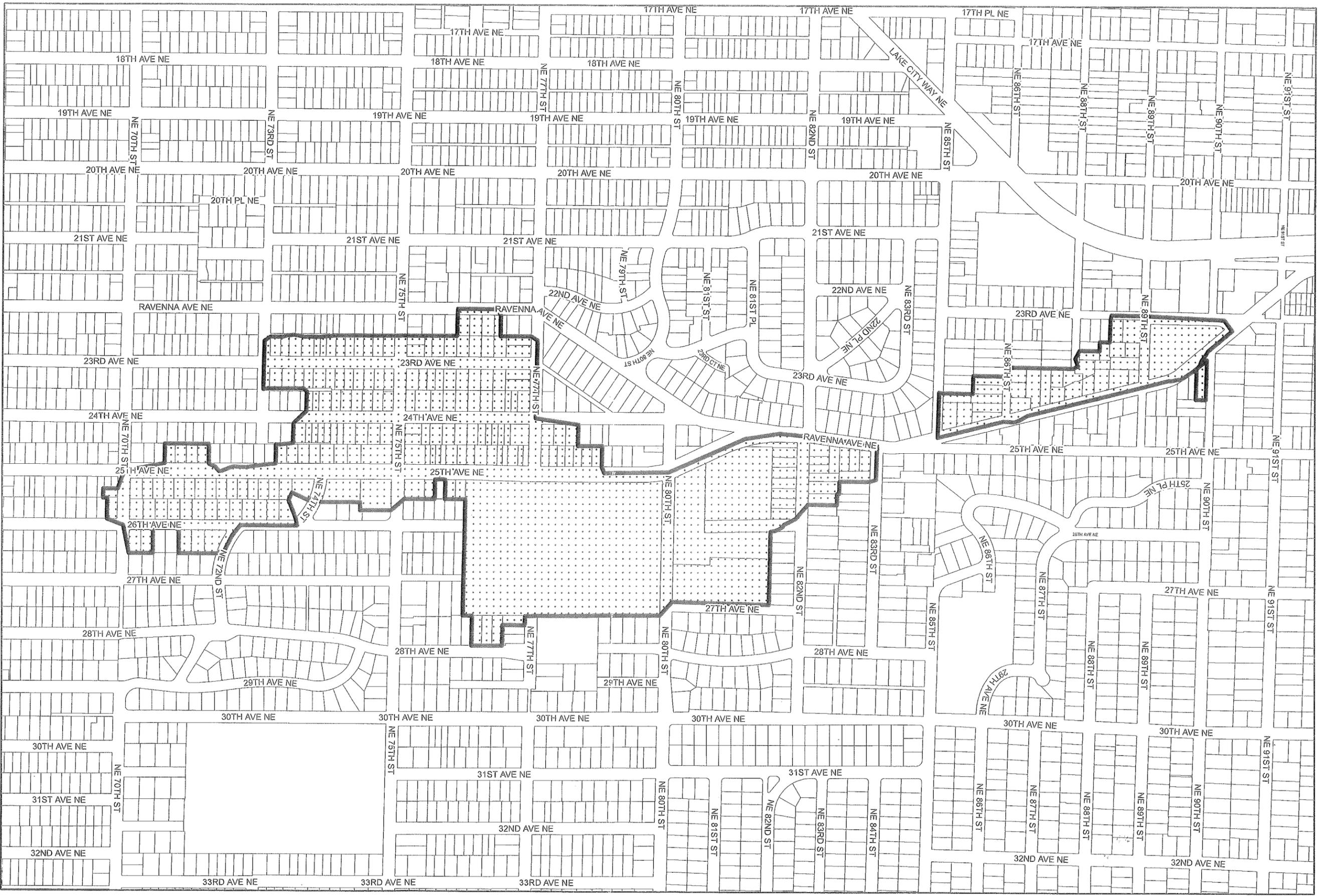
Peat Settlement-Prone Area

-  Category I
-  Category II



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Peat Settlement-prone Area Boundaries Maps

Map A 4

Legend

Peat Settlement-Prone Area

Category I

Category II

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Peat Settlement-prone Area Boundaries Maps

Map A 5

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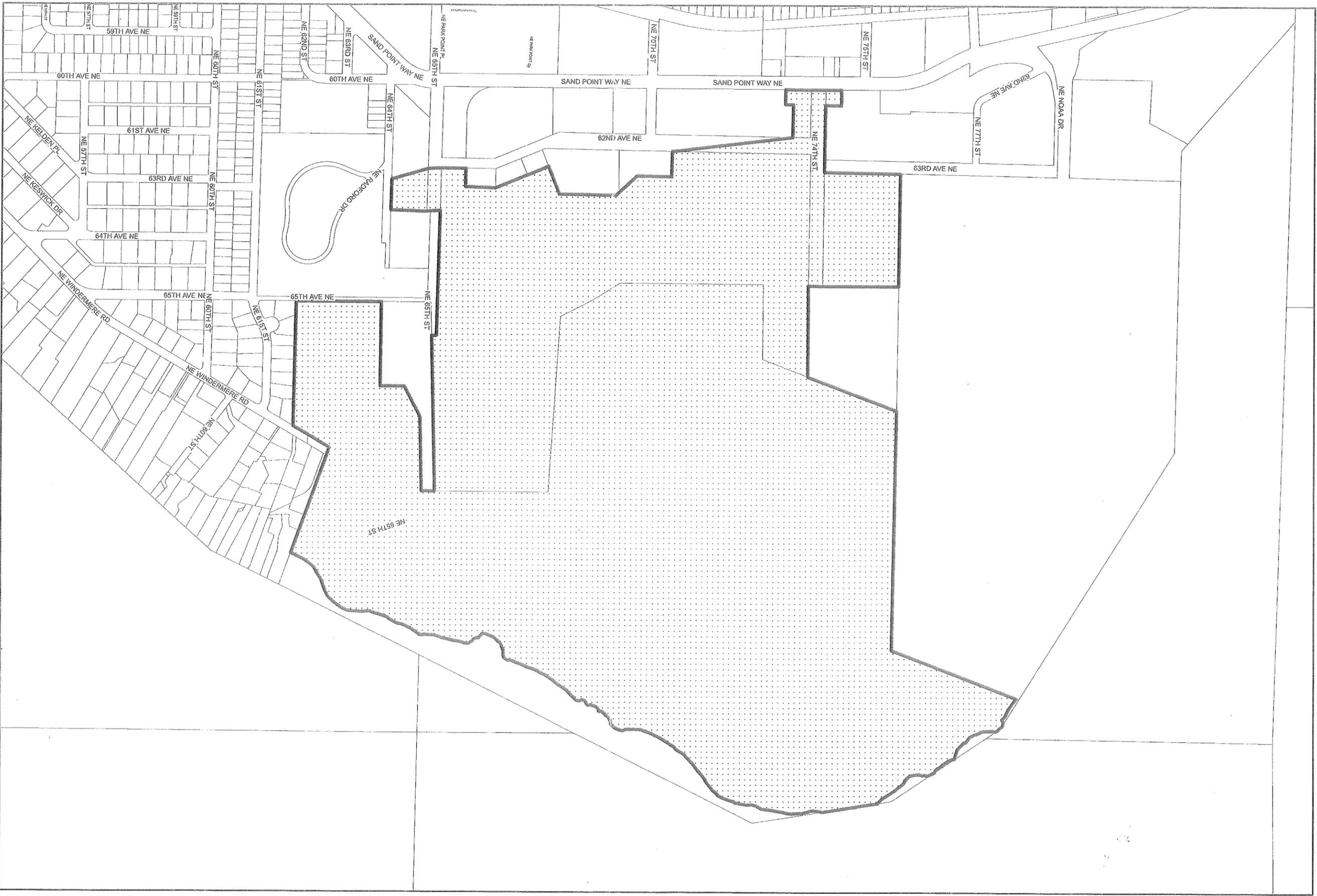
Peat Settlement-Prone Area

-  Category I
-  Category II



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Peat Settlement-prone Area Boundaries Maps

Map A 6

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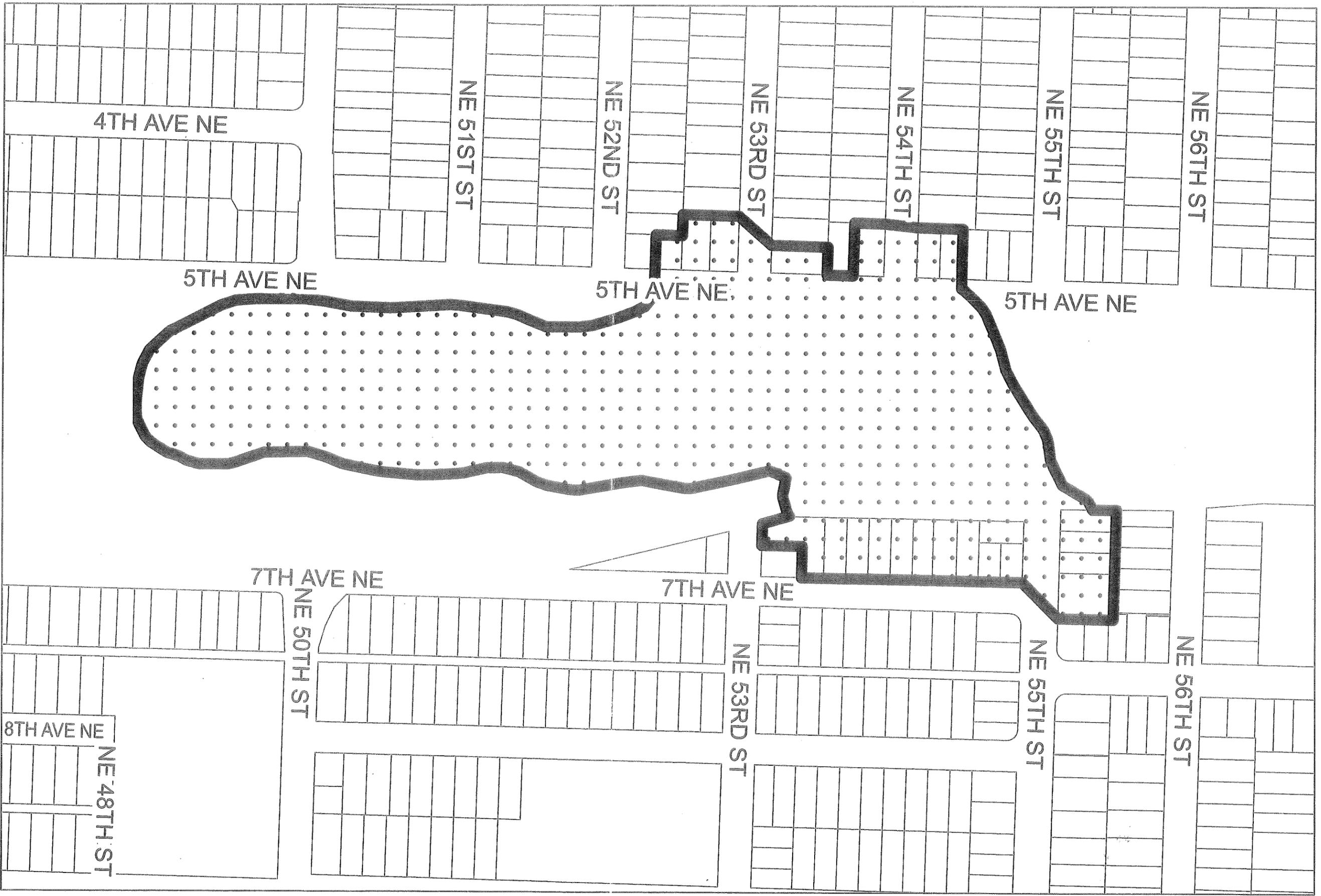
Peat Settlement-Prone Area

-  Category I
-  Category II

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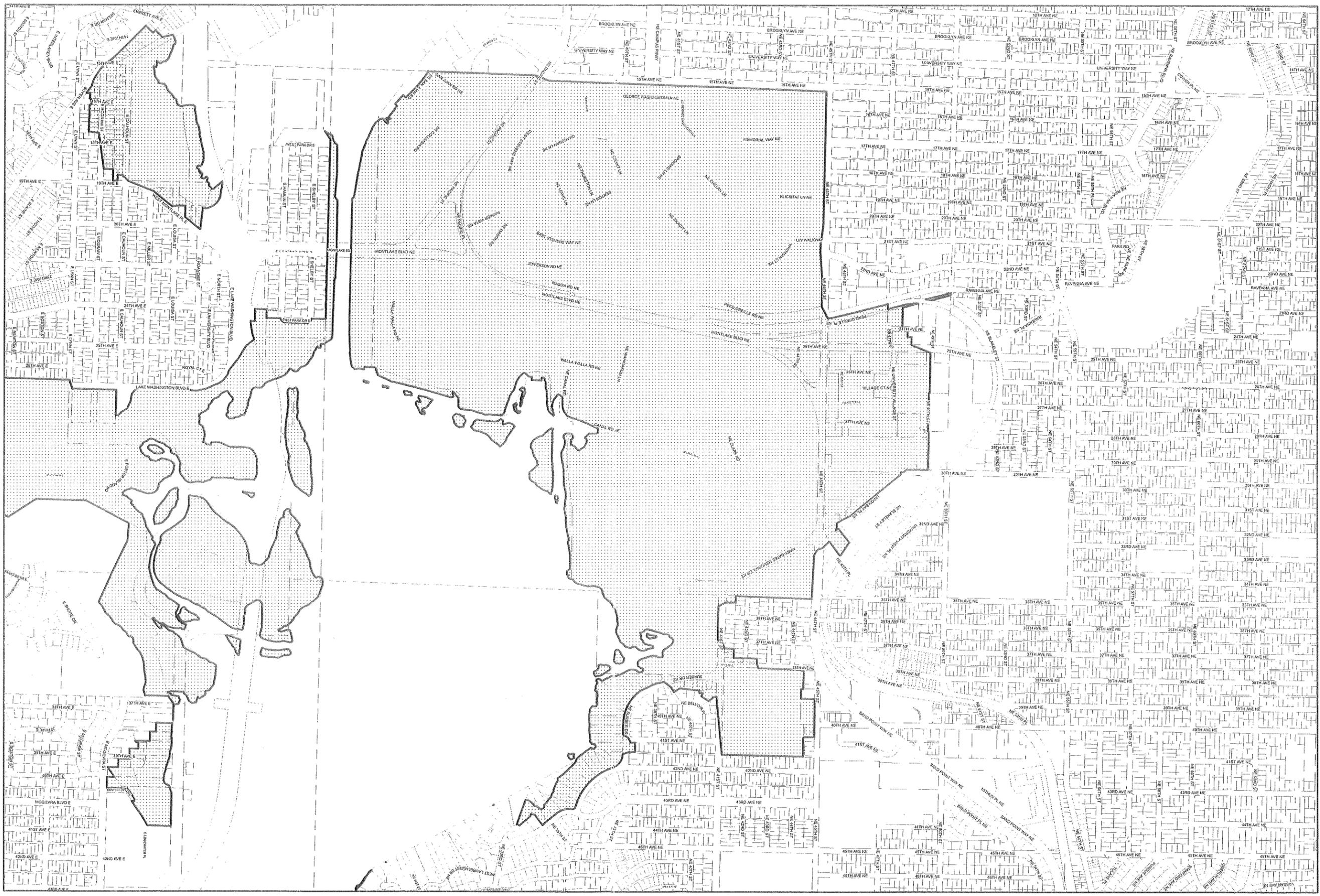


**Peat Settlement-prone
Area Boundaries Maps**
Map A 7

Legend
 Peat Settlement-Prone Area
 Category I
 Category II

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Peat Settlement-prone Area Boundaries Maps

Map A 8

Legend

Peat Settlement-Prone Area

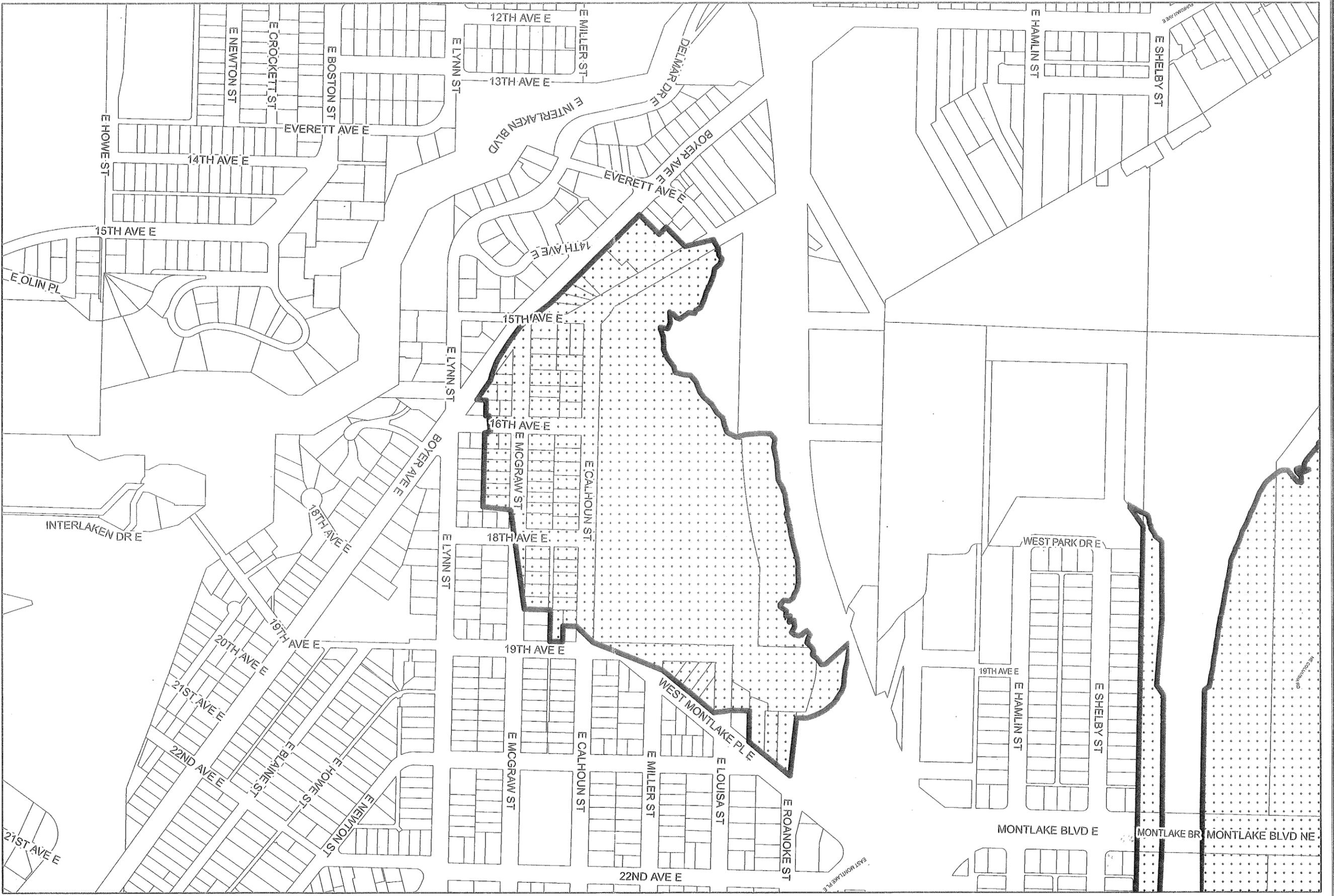
-  Category I
-  Category II

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Peat Settlement-prone Area Boundaries Maps Map A 9

Legend

Peat Settlement-Prone Area

-  Category I
-  Category II

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Peat Settlement-prone Area Boundaries Maps

Map A10

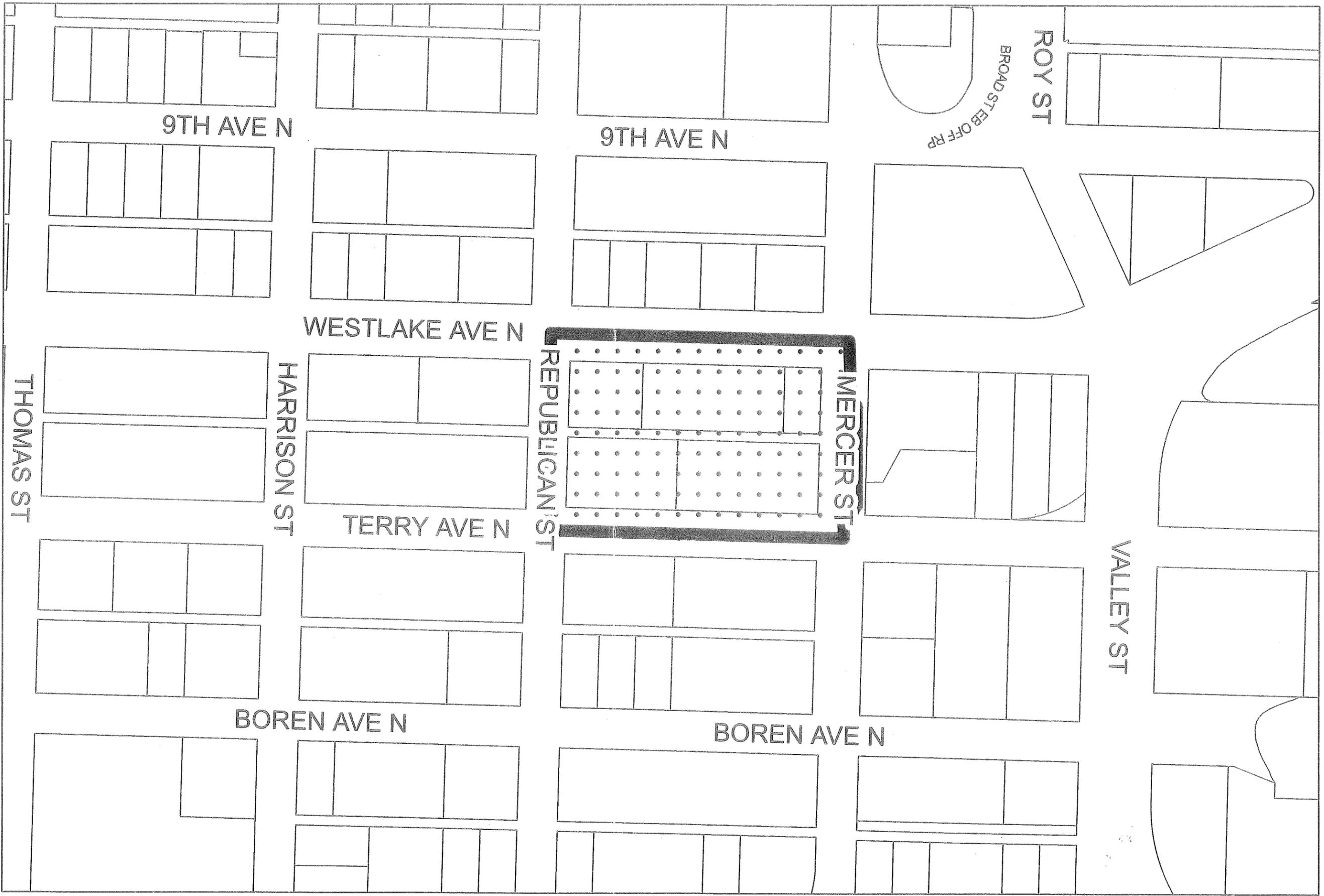
Legend

-  Peat Settlement-Prone Area
-  Category I
-  Category II



0 500 1 000 2 000 Feet

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**Peat Settlement-prone
Area Boundaries Maps**

Map A11

Legend

Peat Settlement-Prone Area

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**Peat Settlement-prone
Area Boundaries Maps**

Map A12

Legend

Peat Settlement-Prone Area

Category I

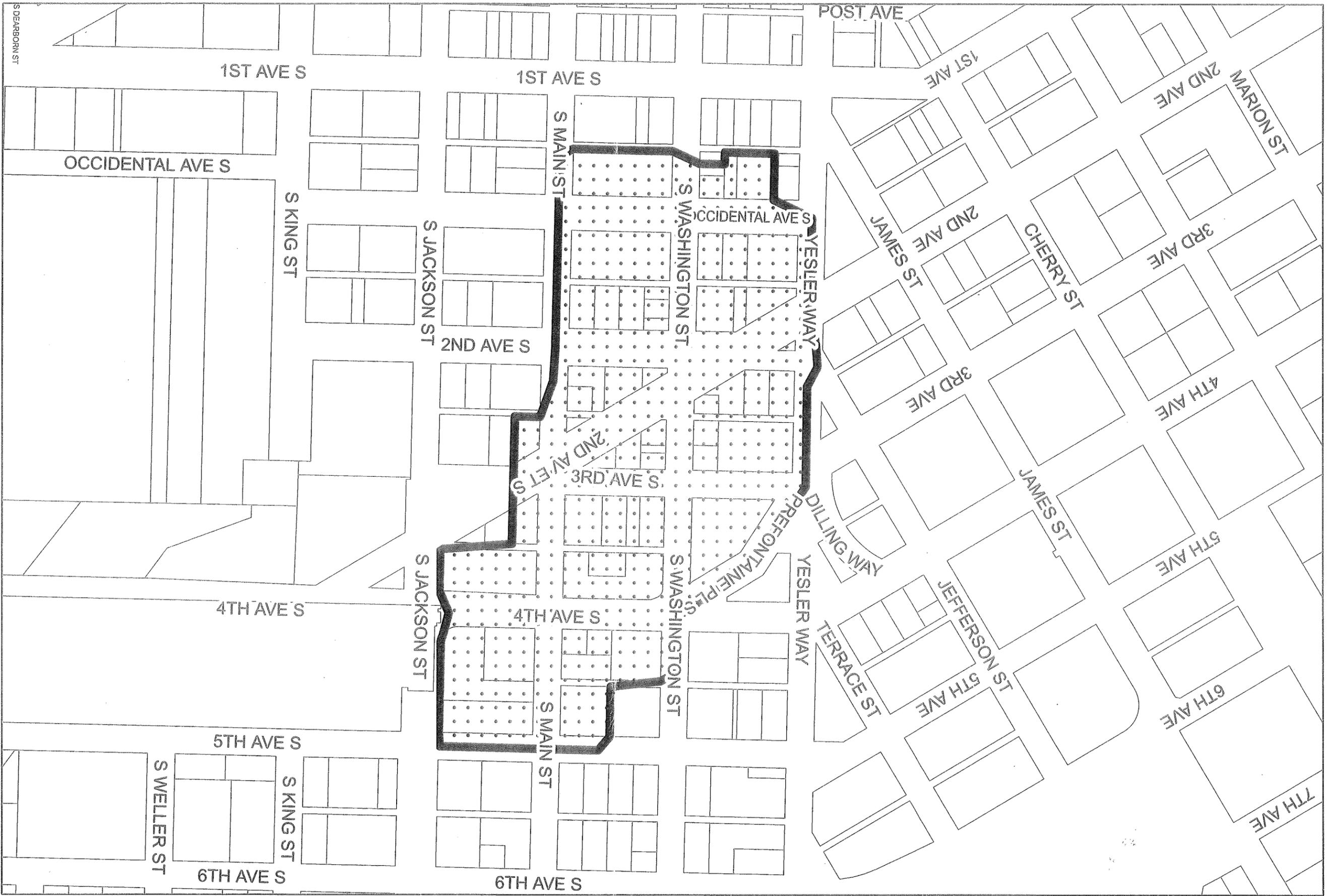
Category II

0 125 250 500 Feet

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Peat Settlement-prone Area Boundaries Maps

Map A13

Legend

Peat Settlement-prone Area

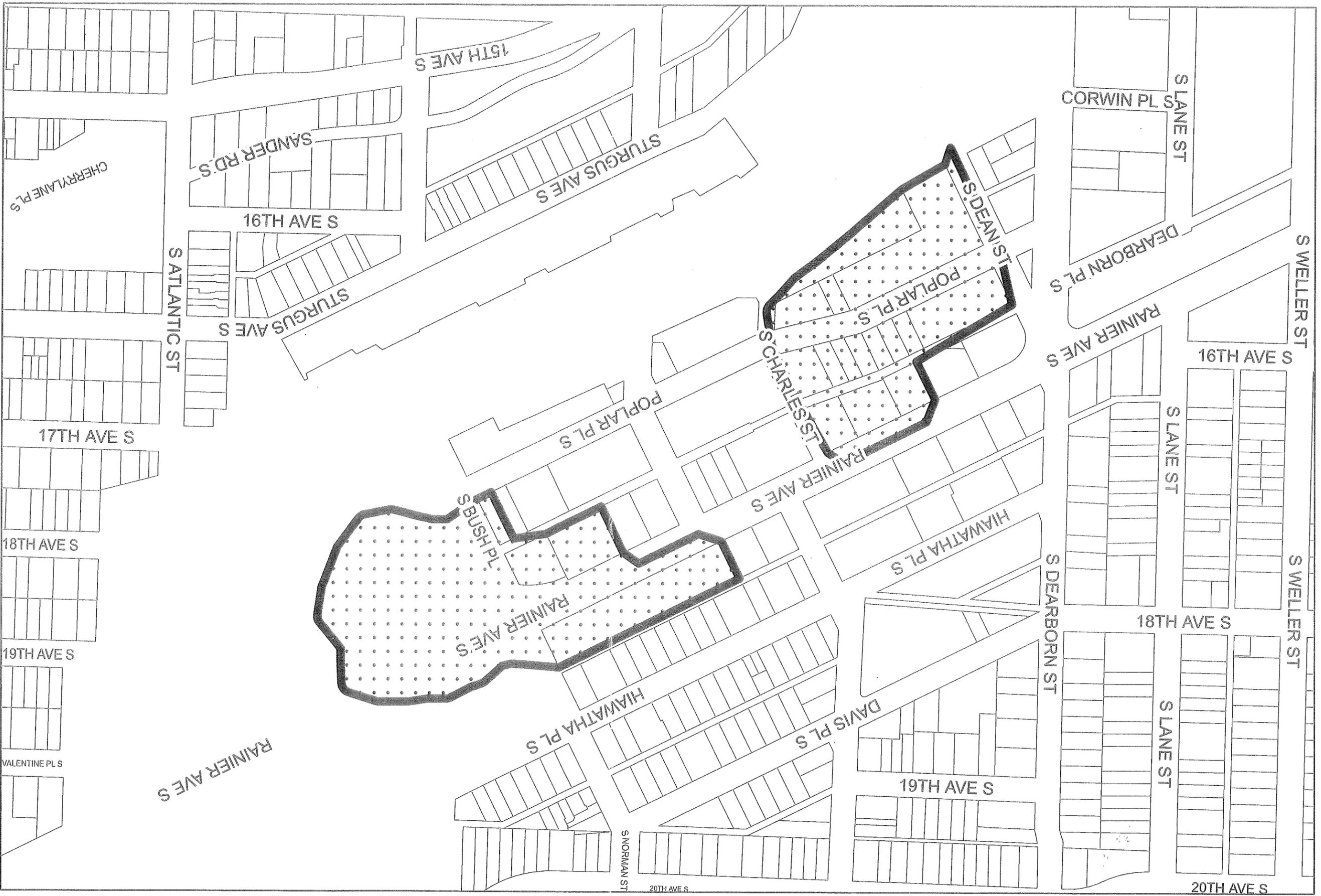
-  Category I
-  Category II



0 165 330 660 Feet

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**Peat Settlement-prone
Area Boundaries Maps**

Map A14

Legend

Peat Settlement-Prone Area

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-  Category II



0 170 340 680 Feet

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**Peat Settlement-prone
Area Boundaries Maps**

Map A15

Legend

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**Peat Settlement-prone
Area Boundaries Maps**

Map A16

Legend

Peat Settlement-Prone Area

Category I

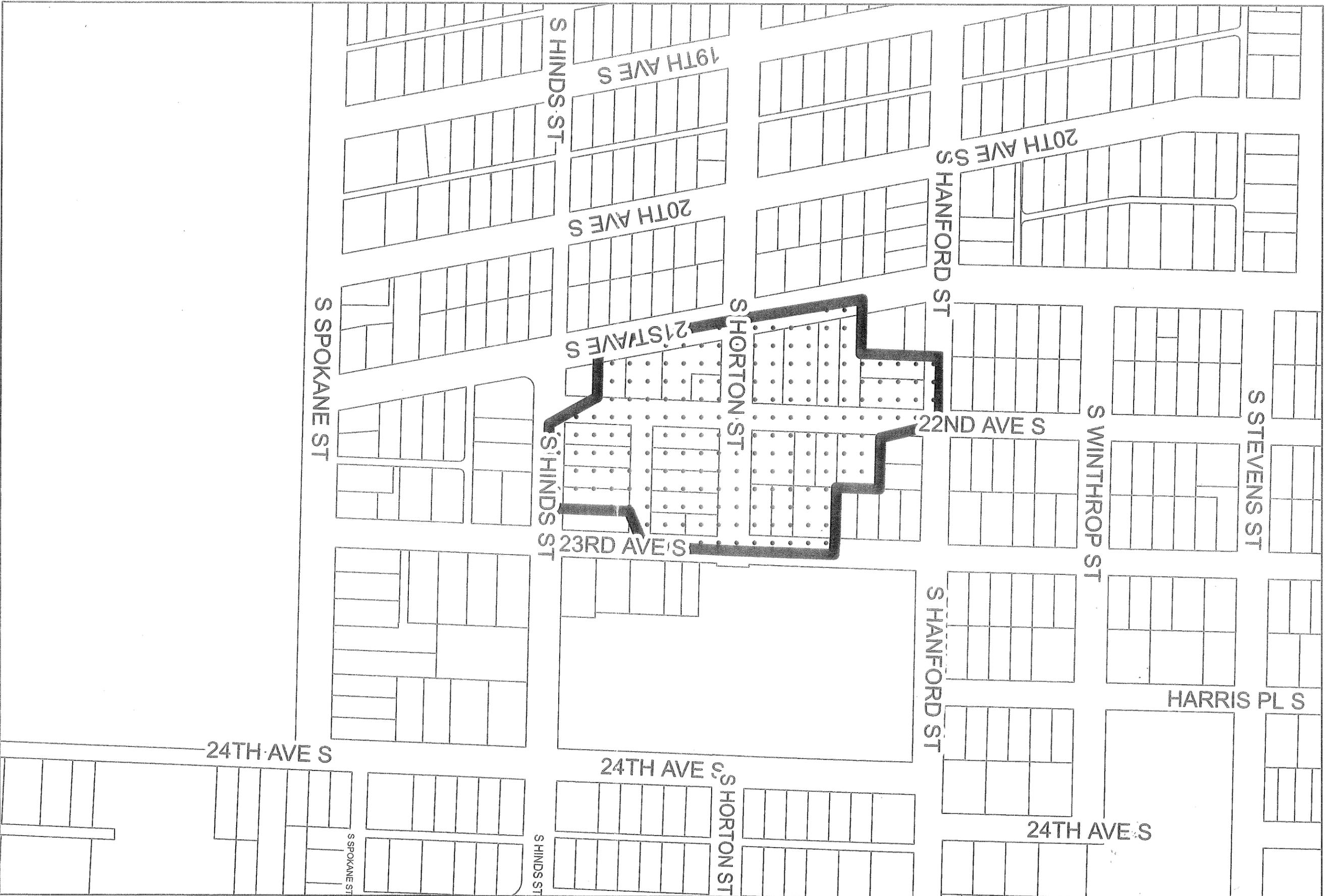
Category II

0 110 220 440 Feet

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**Peat Settlement-prone
Area Boundaries Maps**

Map A17

Legend

Peat Settlement-Prone Area

Category I

Category II

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0 135 270 540 Feet





**Peat Settlement-prone
Area Boundaries Maps**

Map A18

Legend

-  Peat Settlement-Prone Area
-  Category I
-  Category II



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Peat Settlement-prone Area Boundaries Maps

Map A19

Legend

Peat Settlement-Prone Area

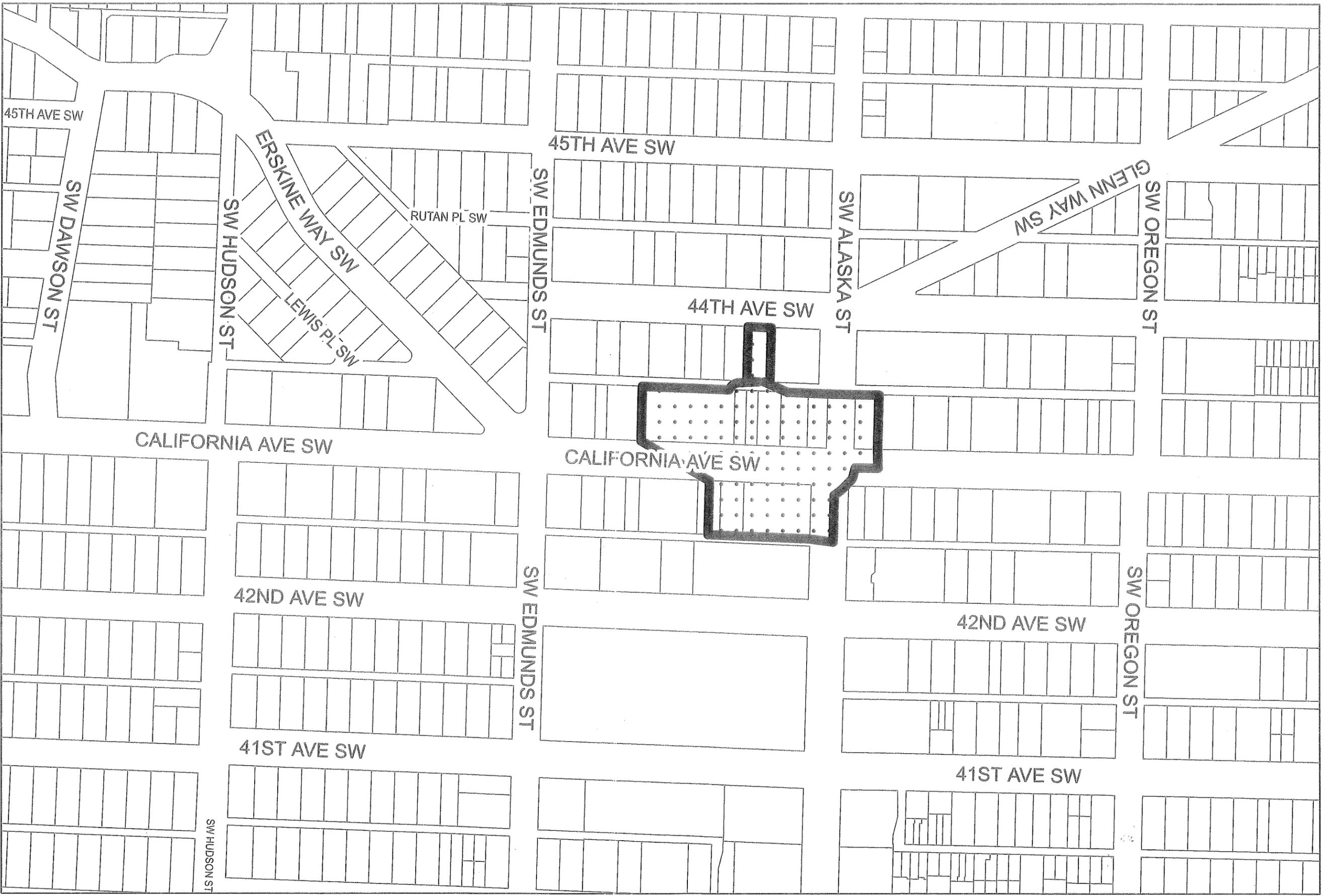
-  Category I
-  Category II

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0 180 360 720 Feet

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CITY
OF
SEATTLE



**Peat Settlement-prone
Area Boundaries Maps**

Map A20

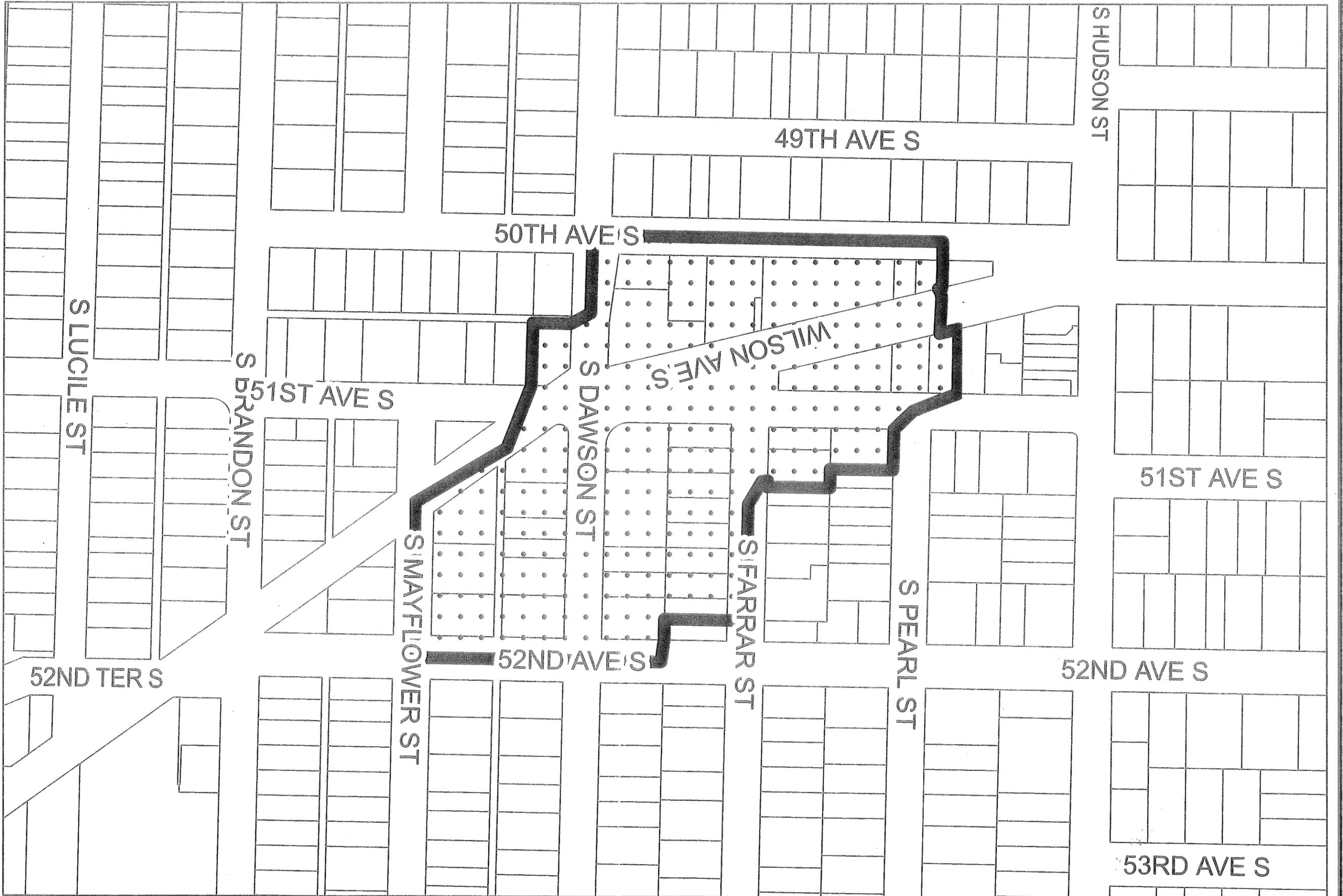
Legend

-  Peat Settlement-Prone Area
-  Category I
-  Category II



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**Peat Settlement-prone
Area Boundaries Maps**

Map A21

Legend

Peat Settlement-Prone Area

Category I

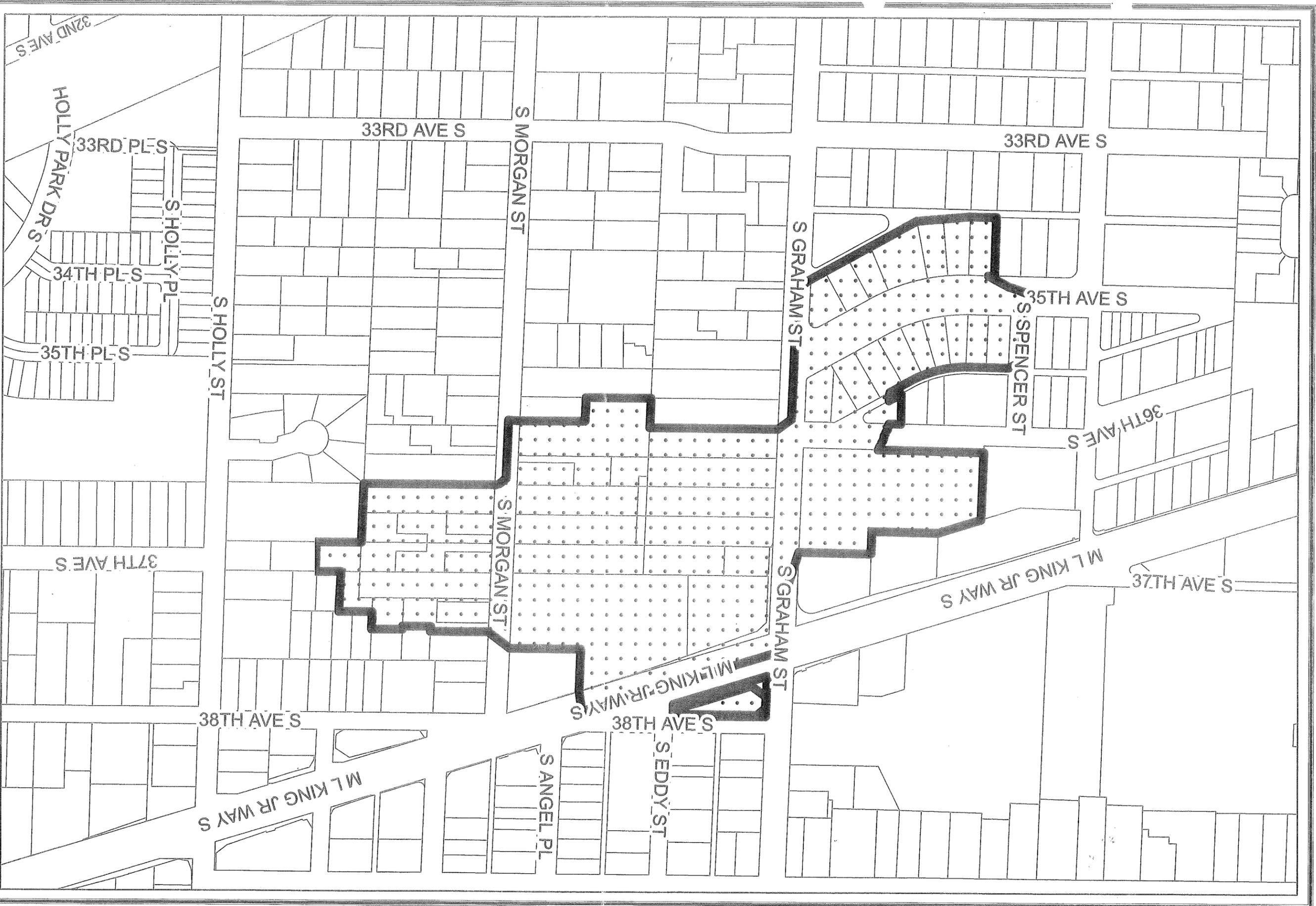
Category II

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0 85 170 340 Feet





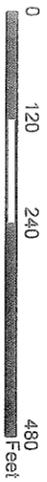
**Peat Settlement-prone
Area Boundaries Maps**

Map A22

Legend

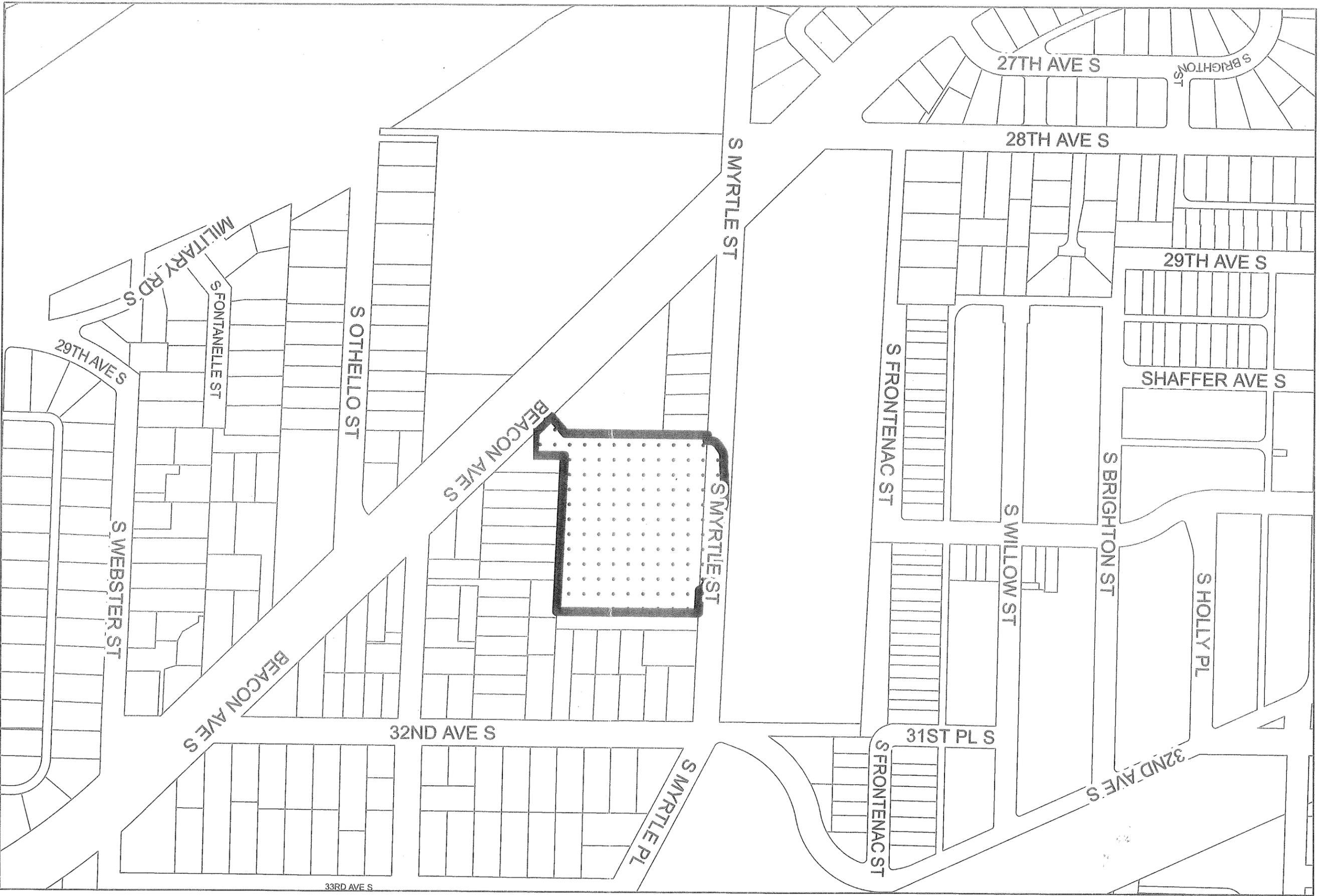
Peat Settlement-Prone Area

-  Category I
-  Category II



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**Peat Settlement-prone
Area Boundaries Maps**

Map A23

Legend

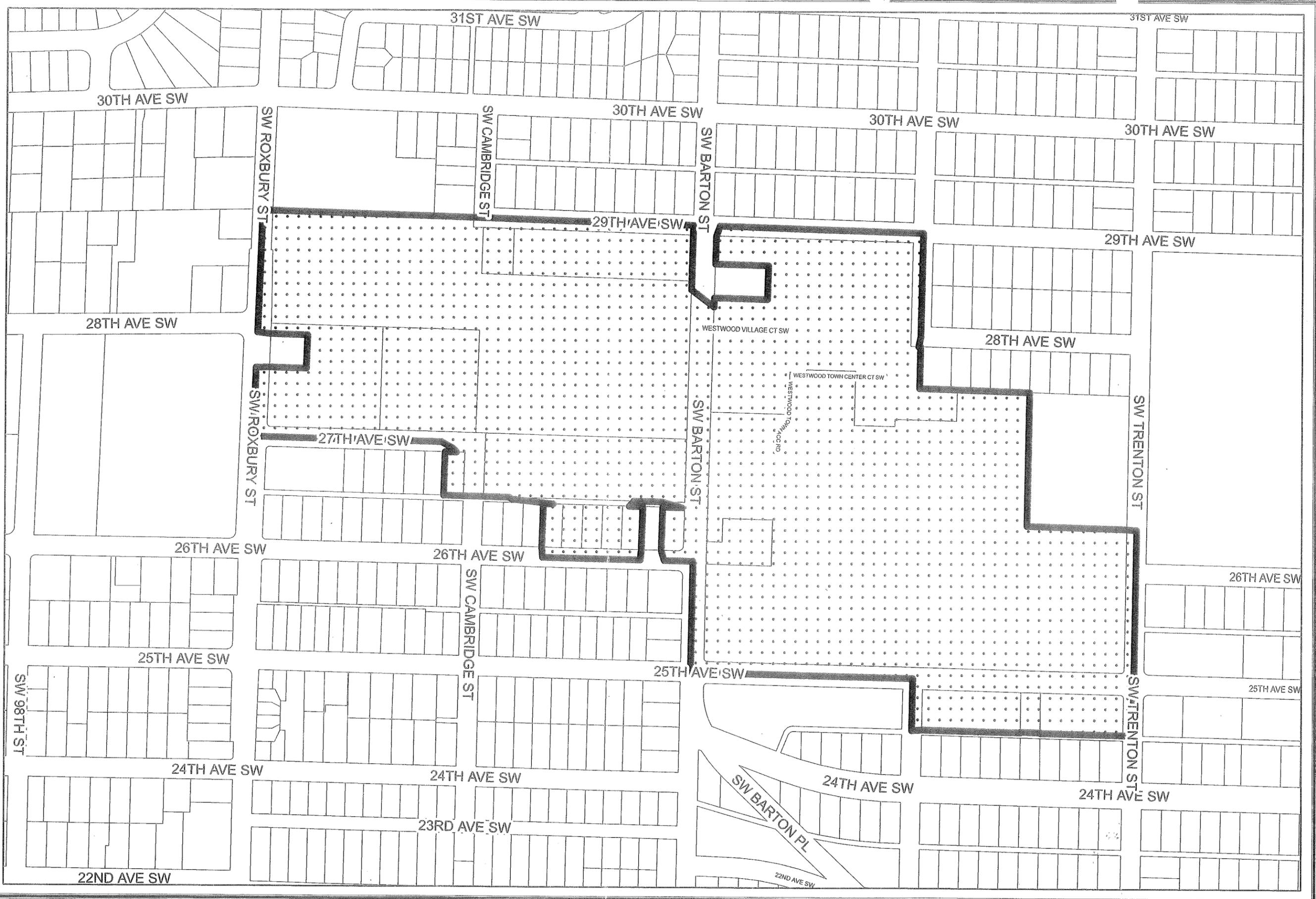
-  Peat Settlement-Prone Area
-  Category I
-  Category II



0 120 240 480
Feet

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**Peat Settlement-prone
Area Boundaries Maps**

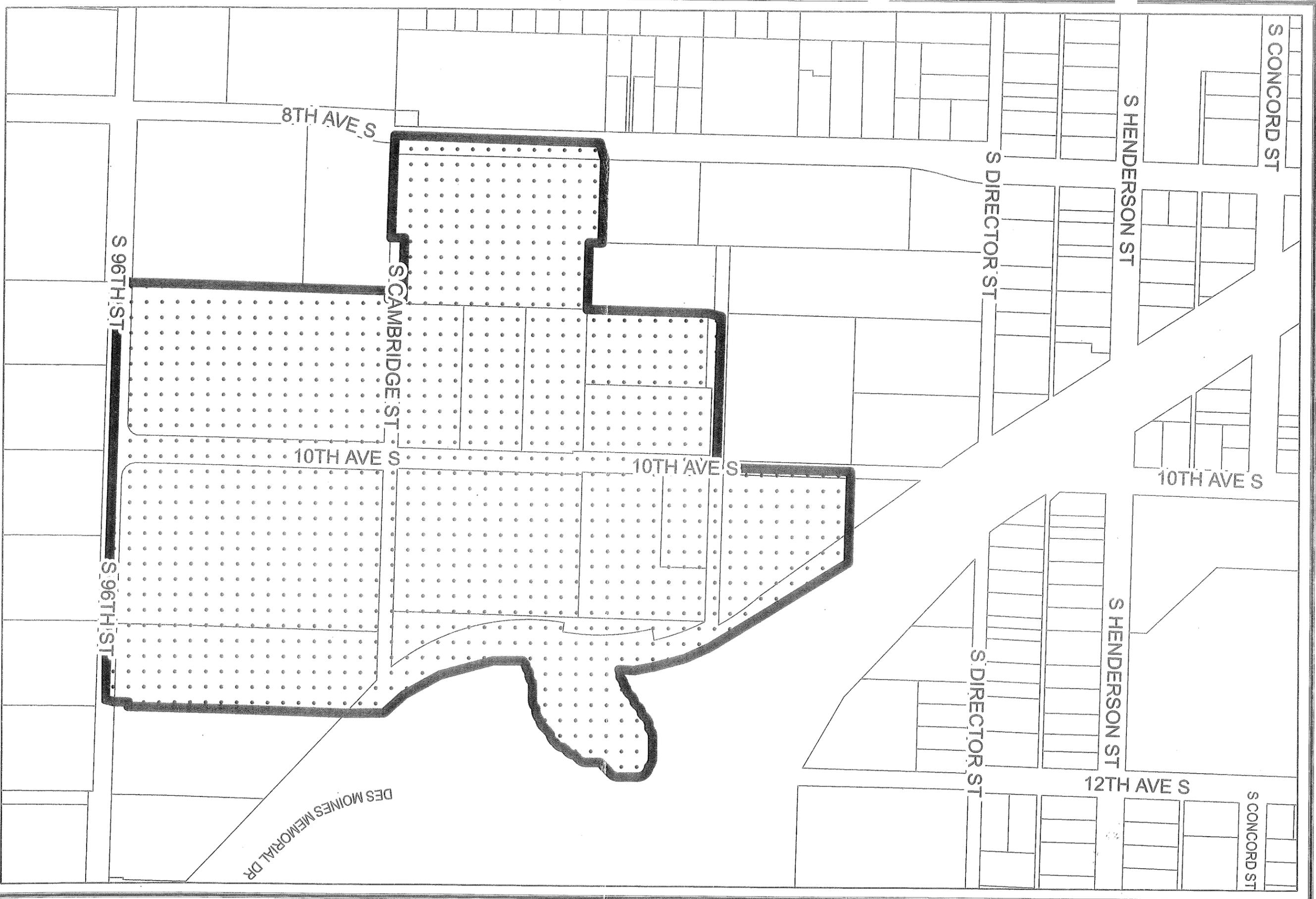
Map A24

Legend

-  Peat Settlement-Prone Area
-  Category I
-  Category II

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**Peat Settlement-prone
Area Boundaries Maps**

Map A25

Legend

-  Peat Settlement-Prone Area
-  Category I
-  Category II



0 115 230 460 Feet

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Best Available Science Report For Peat Settlement-prone Geological Hazard Areas

The report was prepared by Brennon Staley, MUP in Urban Planning, and reviewed by Susan Chang, Ph.D. in Civil Engineering, P.E.

Overview

Peat is an accumulation of partially decayed organic plant material that typically forms in wetland where lack of oxygen and acidic conditions inhibit complete decay. Unconsolidated peat deposits are generally characterized by a fibrous structure exhibiting weak compressive strength and high void ratios (i.e., containing significant void space).

Peat deposits are subject to settlement when loaded with additional weight or when groundwater levels are lowered. Lowering of the groundwater level reduces the buoyancy of overlying soils, thus increasing the pressure on the peat deposit and potentially resulting in compression. Settlement can occur where new fill or structures load soil or where groundwater levels are lowered due to sump pumps, temporary construction dewatering withdrawals, or other drainage projects. Because settlement can be induced by lowering of the groundwater table as well as by direct loading of the soil, settlement of peat deposits can occur a significant distance from the originating development activity because water withdrawals can influence the water table off-site.

Seattle Context

In the City of Seattle, peat deposits have typically formed in topographical basins created during the most recent glacial retreat and in the nearshore areas of lakes, the floodplains of the Duwamish River, depressions along modern streams, and marine estuaries. The lowering of Lake Washington by nine feet in 1916 also exposed significant areas of former lake bottom that contain peat deposits. As the City developed, these boggy areas were often filled to reclaim marshy areas considered to be a nuisance due to standing water and odors as well as to provide more developable land. Consequently, some of the many peat deposits have been buried and now support development throughout the City.

Urban development in these areas has led to further alterations which have impacted the peat deposits and their settlement potential. Drainage projects were initiated in some areas of the City to drain wet areas and redirect stream flows. Installation of storm drains and sewer systems, sump pumps, and impervious surface have reduced the amount of groundwater recharge through diversion of stormwater and groundwater inflow. Regrading projects and

public utilities may also have changed water flow directions and created new flow corridors where granular fill has created new pathways of increased permeability. Together, these modifications have led to significant cumulative impacts where altered hydrology has created new equilibrium states, as well as acute impacts where individual development projects adversely affected nearby properties.

Mechanics of Peat Settlement

The magnitude of settlement occurring in a particular location is based on a number of factors including:

- Geotechnical characteristics of the peat
- Thickness of the peat deposit
- Existing pressure on the peat
- Change in pressure on the peat
- Historic loading of the peat

These relationships can be expressed in the following equation:

$$\text{Expected Total Settlement} = s_t = s_i + s_c + s_s$$

where s_i = immediate settlement
 s_c = primary consolidation
 s_s = secondary compression.

Immediate settlement is only of concern during fill or structure loading. Because these concerns are adequately addressed by existing building code standards, they are not a topic for this paper, which remains focused on potential off-site impacts.

Primary consolidation is a time-dependent settlement process that occurs in saturated fine-grained soils that have low permeability. The settlement is due to water slowly being forced from the void spaces of the soil due to increases in load on the soil. For soils such as peat and other highly organic soils with high natural water content and high void ratios, primary consolidation settlements can be large.

Primary consolidation is made up of a recompression component (settlement due to loading up to the maximum past pressure experienced by the peat) and a virgin compression component (settlement due to loading greater than the maximum past pressure experienced by the peat). Primary consolidation can be estimated with parameters from laboratory testing using the following equation (Holtz and Kovacs, 1981):

$$s_c = C_r * \frac{H}{1 + e_o} * \log\left(\frac{p_p'}{p_o'}\right) + C_c * \frac{H}{1 + e_o} * \log\left(\frac{p_f'}{p_p'}\right)$$

where s_c = primary consolidation
 C_r = recompression index
 C_c = compression index
 H = thickness of the peat
 e_o = initial void ratio (volume of voids divided by volume of solids)
 p_o' = initial effective stress on the peat
 p_p' = maximum past pressure on the peat
 p_f' = final effective stress on the peat

Primary consolidation settlement can take several months to complete.

Secondary compression is a continuation of the volume change that starts during primary consolidation, but it occurs at a much slower rate. It constitutes a major part of the total settlement of peats and other highly organic soils, and it may continue for an indefinite time period, creating a continuing hazard. Secondary compression can be estimated with parameters from laboratory testing and the following equation:

$$s_s = C_\alpha * \frac{H}{1 + e_p} * [\Delta \log(t)]$$

where s_s = secondary compression
 C_α = secondary compression index
 H = thickness of the peat
 e_p = void ratio at end of primary consolidation
 t = time period being considered for design

Once consolidation has occurred, peat deposits will never return to their original state, although minimal rebound is possible if weight is removed or the water level increases.

Estimates of the expected settlement due to groundwater table drawdown derived from the preceding formulas are included in Tables 1 and 2. The settlement estimates were based upon the following with the understanding that peat settlement properties can be highly variable:

- (1) consolidation parameters from the WSDOT Geotechnical Design Manual of $C_{ce} = C_c / (1 + e_o) = 0.4$ and $C_{\alpha e} = 0.06 * C_{ce}$
- (2) initial water table at 2 feet below the ground surface drawn down to 7 feet below the ground surface

Table 1: Estimated primary settlement (in inches) expected due to groundwater table drawdown from 2 feet below surface to 7 feet below surface.

Depth to top of peat deposit (ft)	Vertical Thickness of Peat Deposit			
	2 ft thickness	3 ft thickness	5 ft thickness	10 ft thickness
0	0	½	1½	11
5	2	3	5	9
10	1½	2	3½	6½
20	1	1	2	4

Table 2: Estimated total settlement (in inches) expected due to groundwater table drawdown from 2 feet below surface to 7 feet below surface.

Depth to top of peat deposit (ft)	Vertical Thickness of Peat Deposit			
	2 ft thickness	3 ft thickness	5 ft thickness	10 ft thickness
0	0	½	4	16
5	3	4½	7½	14
10	2½	3½	6	11
20	2	2½	4½	9

Effects of Settlement

The impacts of settlement can be significant, particularly where differential settlement occurs due to a peat deposit having variable thickness, groundwater flow directions, slopes, differential loading, or previous compressions. Common damages from settlement include uneven or cracked foundations, cracks in the interior finishes, sticking windows and doors, broken underground utilities, and uneven sidewalks and roads. These problems may cause existing structures to become more prone to damage during earthquakes. Flooding may also occur both as pipes break and settlement lowers the elevation of yards and structures, creating ponding, or even lowering areas below the water table. Because settlement occurs gradually, the impacts of additional loading or groundwater withdrawals may appear gradually after an initial modification.

Historic Settlement in Seattle

Evidence of gradual settlement has been found in many localized areas of Seattle. Areas in Greenwood, the most studied area of peat-rich soils, have been experiencing documented settlement of roads and structures as far back as 1958 (Shannon & Wilson 2004). Union Bay, one of the deepest known peat deposits in Washington State, has also experienced significant recorded settlement (Montlake Landfill Work Group, 1999).

In 2001, sections of the Greenwood neighborhood began to experience unexpected acute settlement. Developed on the location of historic wetlands, substantial subsurface peat deposits have been found under portions of

Greenwood including part of the Greenwood business district and the residential area north and west of NW 85th Street and Greenwood Avenue North. This area, commonly referred to as the “Greenwood Bog,” constitutes a topographical depression bordered by Phinney Ridge to the east and Crown Hill and Blue Ridge to the west. Lowered groundwater levels resulting from development along Greenwood Avenue North appear to be a cause of this settlement, although insufficient data exists to pinpoint an exact source (Shannon & Wilson, 2004).

Data for assessing the effects of settlement in other parts of the City is not readily available.

Peat Studies in Seattle

A number of relevant studies have been conducted in Seattle that have added to the knowledge of peat and peat settlement occurring within the City including the Map of Organic-Rich Deposits developed by GeoMapNW (Troost, 2006) and the Shannon & Wilson Greenwood Subsurface Characterization Study (2004).

The Map of Organic-Rich Deposits (GeoMapNW 2006) project compiled and analyzed boring logs submitted to the City of Seattle in conjunction with permit applications between 1914 and 2006. 33,270 reports were compiled and analyzed to identify subsurface deposits of peat greater than one foot in thickness. These results were then extrapolated based on historic geomorphology and hydrology to estimate the extent of peat deposits as well as other organic-rich geologic units, including wetland, lake, tideflat, and Vashon recessional lake deposits.

Follow-up work completed in June 2007 refined the earlier map and identified discrete bogs. This 2007 map, City of Seattle Identified Bogs, dated June 19, 2007, relied on 34,909 data points. The map shows both discrete bogs and individual borings/data points that indicate a presence of peat in the subsurface. This analysis summarized each of the peat deposits based on four factors that indicate potential risk due to settlement: thickness of peat, depth to peat, depth to groundwater level, and location of groundwater level in relation to peat. This characterization provides a critical resource for determining where much of the City’s peat settlement hazards exist. The map relies on available borehole data, geologic mapping, and geologic interpretation.

Another important study of peat settlement within Seattle is the Greenwood Subsurface Characterization Study (Shannon & Wilson, 2004). This study was commissioned by Seattle Public Utilities in response to acute settlement occurring in the neighborhood to determine underlying geologic conditions. The study developed a map that delineates the former peat bog area and

identifies the depth and thickness of the peat throughout the area. Shannon & Wilson also tested the peat to determine the potential to re-introduce water into the substrata and placed monitoring devices in several locations for a long-term assessment of groundwater flows and levels in the area. The study concluded that settlement in the neighborhood was “likely the result of groundwater removal” occurring due to multiple factors including construction of impervious surface, diversion of stormwater, installation of the 1970s storm drain system, natural groundwater fluctuations, climate change, construction dewatering and permanent drainage systems in subsurface structures. Shannon & Wilson warned that the “continued groundwater removal and the removal of groundwater from other locations within the study area could contribute to additional or new settlement, and should be avoided where settlement could impact structures, utilities, roadways and other improvements.” (Shannon & Wilson, 2004)

Implications for Regulation

Development in areas containing peat deposits can result in settlement where new structures or fill compress underlying peat soils or where modification of the groundwater table increases the effective pressure on underlying peat soils.

To avoid negative impacts from development, it is necessary to ensure both that new structures are designed to prevent or accommodate settlement and that they do not cause settlement off-site through modification of the groundwater table. Regulations should specifically seek to minimize modification of the existing groundwater regime because any modification of existing groundwater regime that removes or redirects groundwater even for a short period may lead to local groundwater depressions resulting in settlement. Alternatively, modifications of the groundwater table that increase groundwater levels, although they would not lead to settlement, may also be undesirable as they can not significantly reverse previous settlement activity and may lead to flooding.

Determination of areas that should be included in potential regulations should consider all the variables impacting settlement potential discussed earlier, including geotechnical characteristics of the peat, peat thickness, existing pressure on the peat, potential changes in pressure on the peat (including groundwater levels), and historic loading of the peat. Within regulated areas, protections should be applied even where geotechnical explorations fail to reveal peat deposits on the site of a proposed development because peat deposits may be present on nearby parcels.

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Technical Review Committee

Steve Erickson; Frosty Hollow Ecological Restoration
Steve Greene; HWA Geosciences
Thomas Kinney; HWA Geosciences
Kathy Troost; University of Washington, GeoMapNW
Mark Varljen; SCS Engineers

Exhibit B to the Ordinance
Best Available Science Report – August 16, 2007